Anisotropic Electron Distributions in Collisionless Reconnection Exhaust

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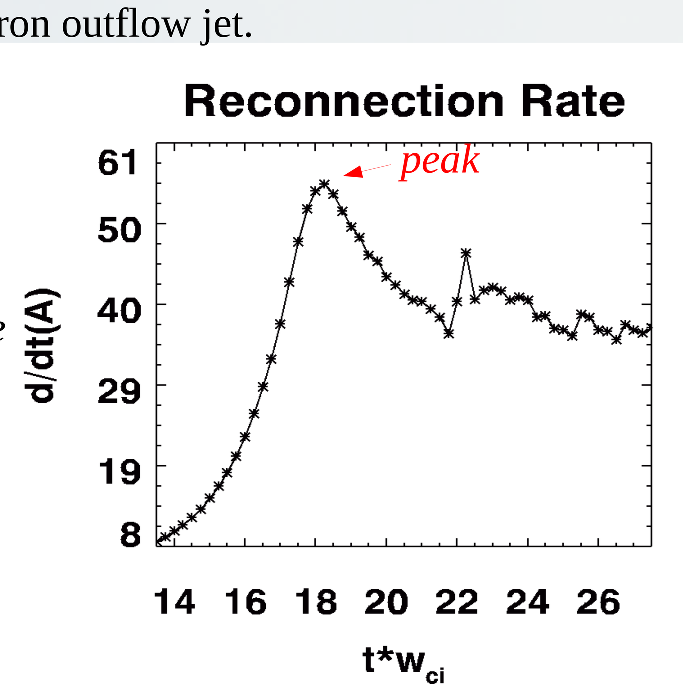
NASA's Magnetospheric Multiscale

Motivation and Context

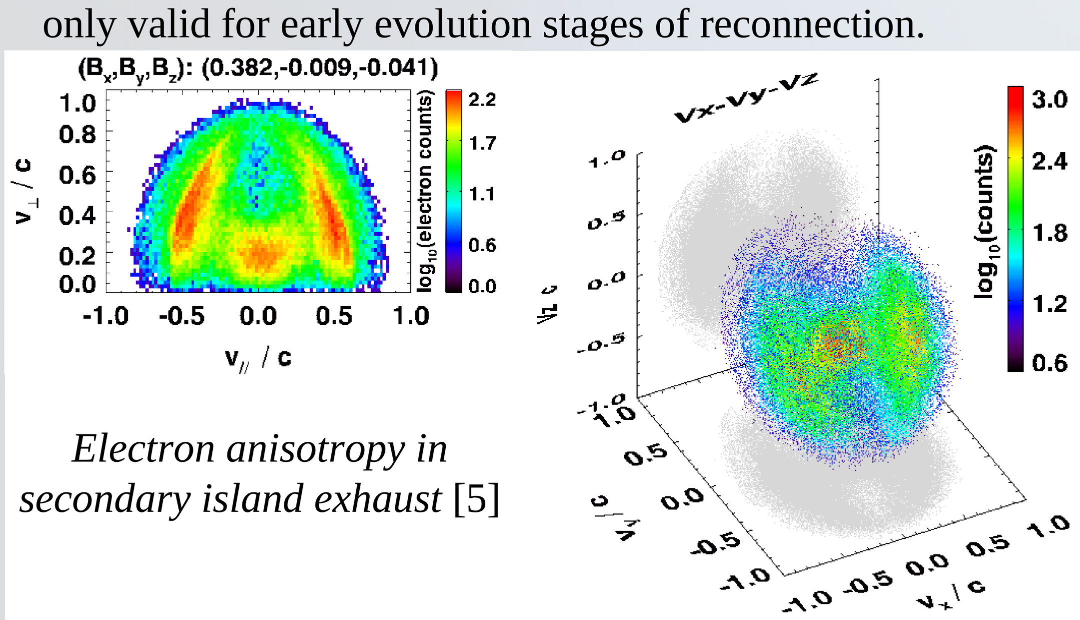
♦ **The purpose of this poster is to report new types of electron anisotropies that develop in the reconnection exhaust region after the reconnection rate peaks.** Previous studies [1,2] concluded that electron distributions in the exhaust are relatively isotropic based on simulations that did not run beyond when the reconnection rate peaks. This poster reports on a simulation that runs for over 10 Ω_{ci}^{-1} after the reconnection rate peak. Using these simulation results, new types of anisotropic electron velocity distributions are discovered and highlighted in this presentation. One recent study reported exhaust anisotropy close to the separatrix region [3]. This poster describes anisotropies from three key regions: **1.** secondary island, **2.** *B*-pileup region, and **3.** region associated with electron outflow jet.



Evolution of the reconnection rate calculated as the time rate of change of the reconnected flux, dA/dt.

Anisotropy in Secondary Island

Magnetic islands (plasmoids) play a crucial role in electron energization [2,6,7]. Notable electron anisotropy has been found in simulation island exhaust regions [5,8] and are likely associated with nonlinear electrostatic wave (electron hole) observations [9]. Prior to our work, electron distributions from island exhausts and open exhausts were assumed to be roughly similar. Our findings show that this assumption is only valid for early evolution stages of reconnection.



Electron anisotropy in secondary island exhaust [5]

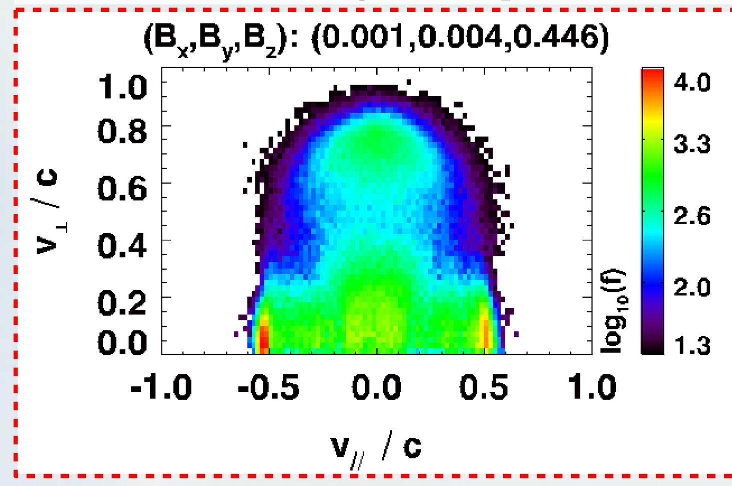
Particle-in-Cell (PIC) Simulation Parameters:

- collisionless, undriven reconnection, with no guide field
- open boundary conditions, perturbation to seed single X-line
- lobe appropriate beta: 0.0028, $N_b / N_o = 0.05$, $T_b / T_o = 0.333$
- $T_i / T_e = 5$ (Harris population), $\omega_{pe} / \Omega_{ce} = 2$, $L / d_i = 0.5$
- $m_i/m_e = 400$, number of particles: ~3.1 x 10^{10}
- particles per cell: 600, number of cells: 10240 x 2560

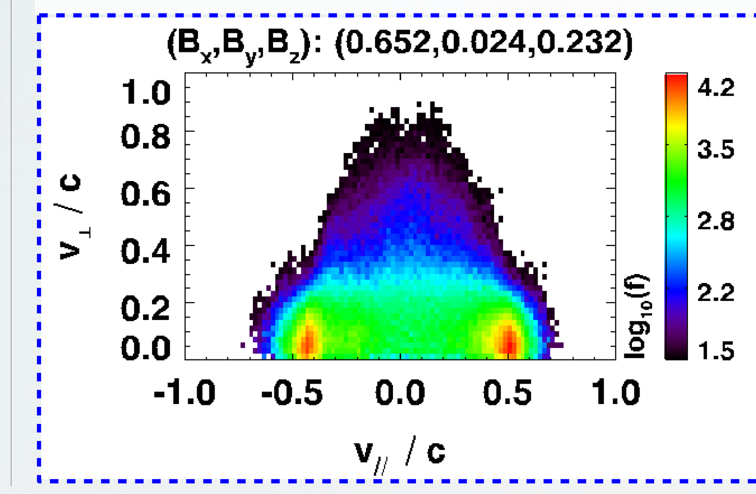
Anisotropy in B-Pileup Region

Multi-component anisotropies occur in the *B*-pileup region where E_y and B_z are largest. The *B*-pileup region has been shown to be associated with whistler wave production [4].

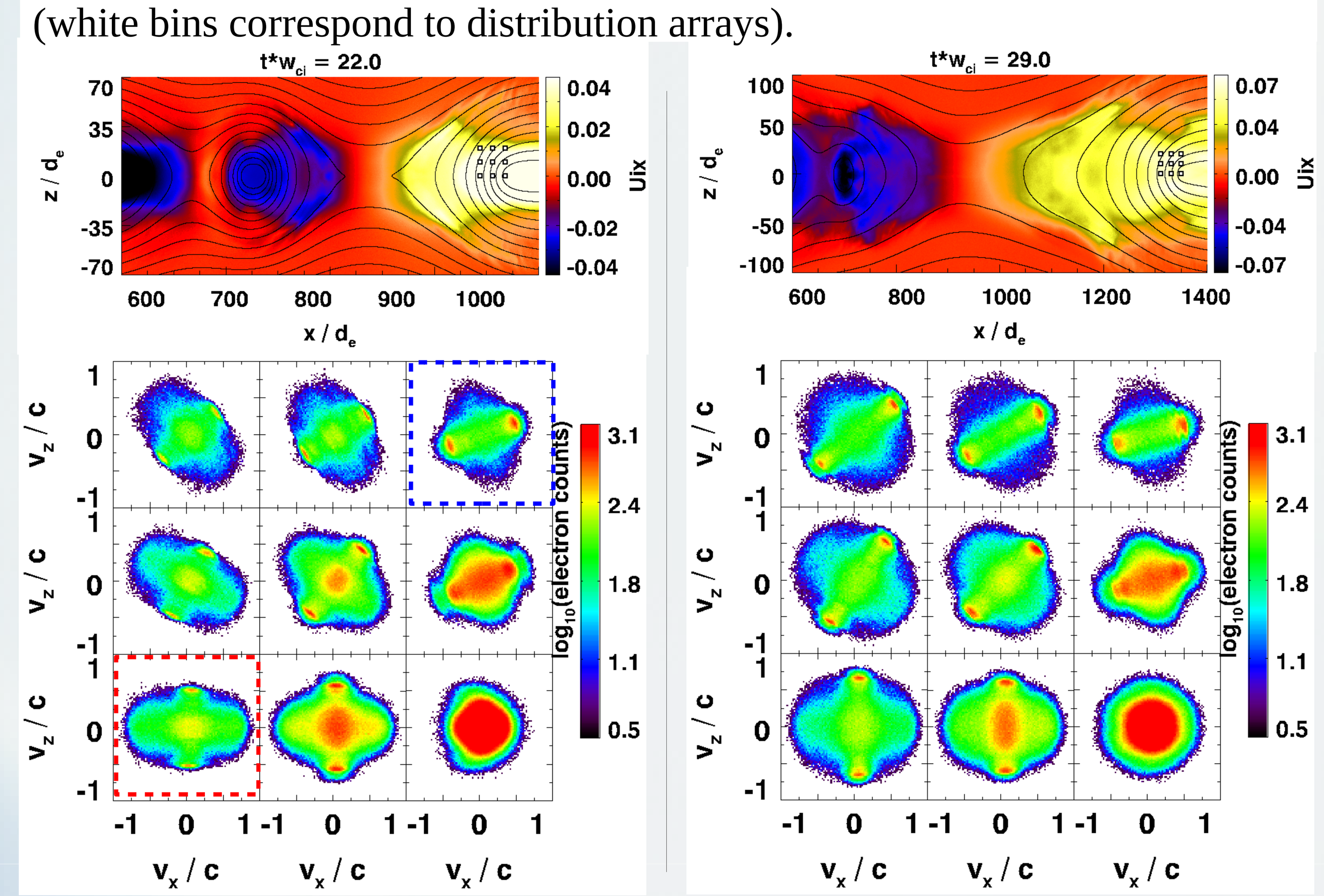
♦ Four distinct populations: one with temperature anisotropy $T_{e\perp} > T_{e//}$, one colder background population, and two counter-streaming beams parallel to ***B***.

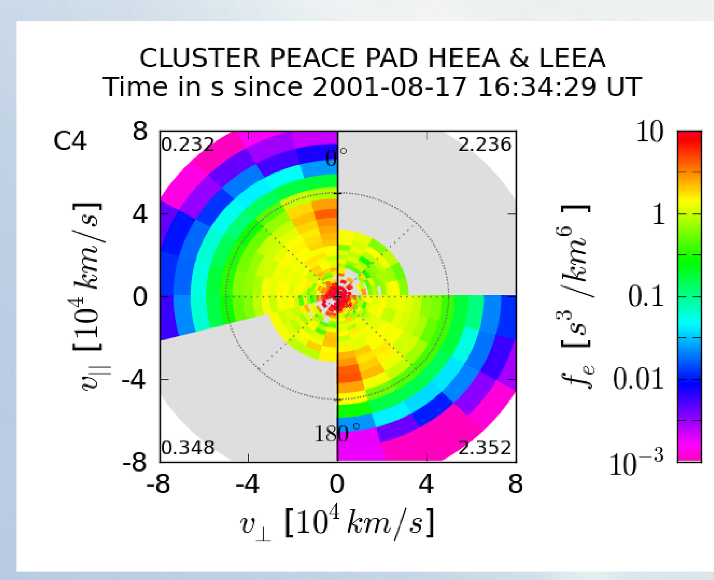


♦ Two counter-streaming populations and a population with $T_{e\perp} > T_{e//}$ anisotropy.



Persistence of Anisotropy: anisotropies last for as long as the simulation (white bins correspond to distribution arrays).





Cluster Data:

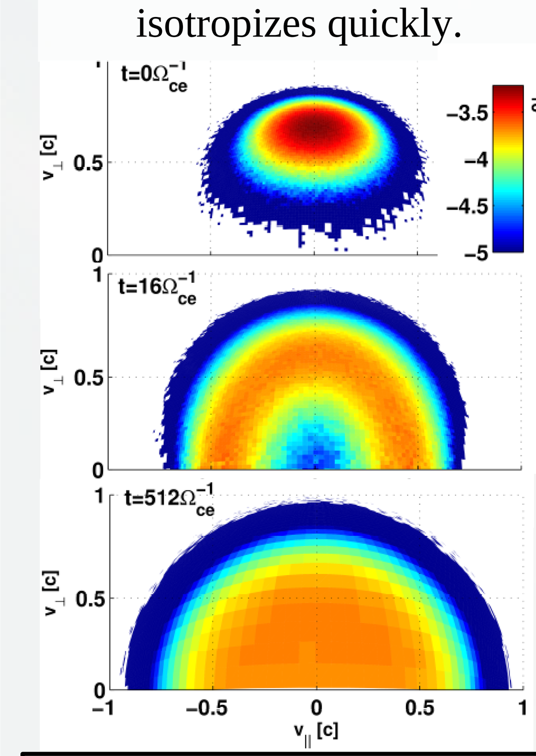
♦ Electron velocity distribution from a magnetotail reconnection exhaust in an ion outflow jet where minimum variance analysis shows $\mathbf{B_x} \approx \mathbf{B_z}$.

♦ Counter-streaming beams parallel to ***B***.

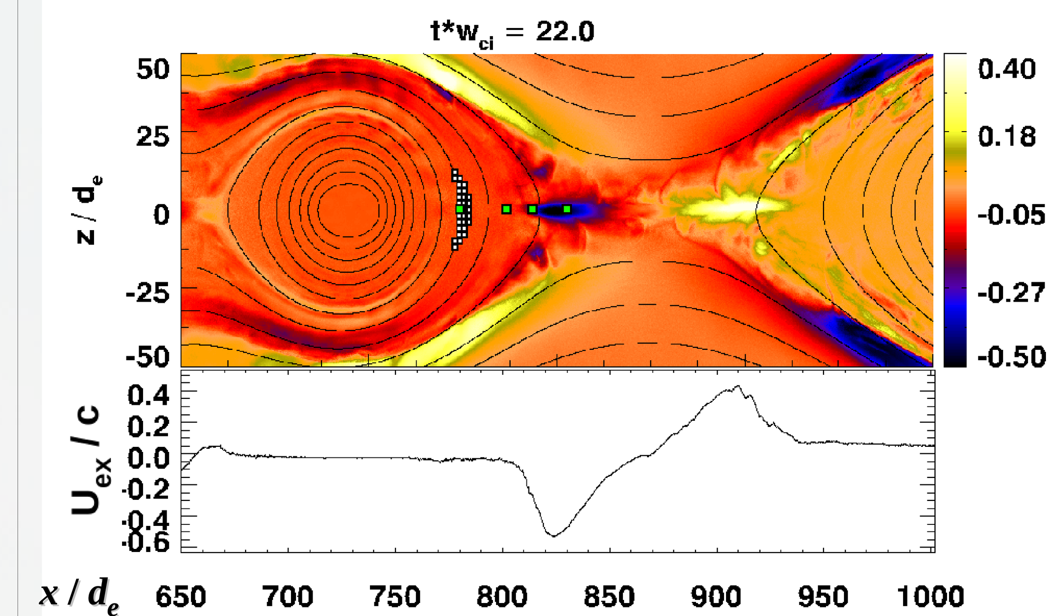
♦ Temperature anisotropy: $T_{e\perp} > T_{e//}$

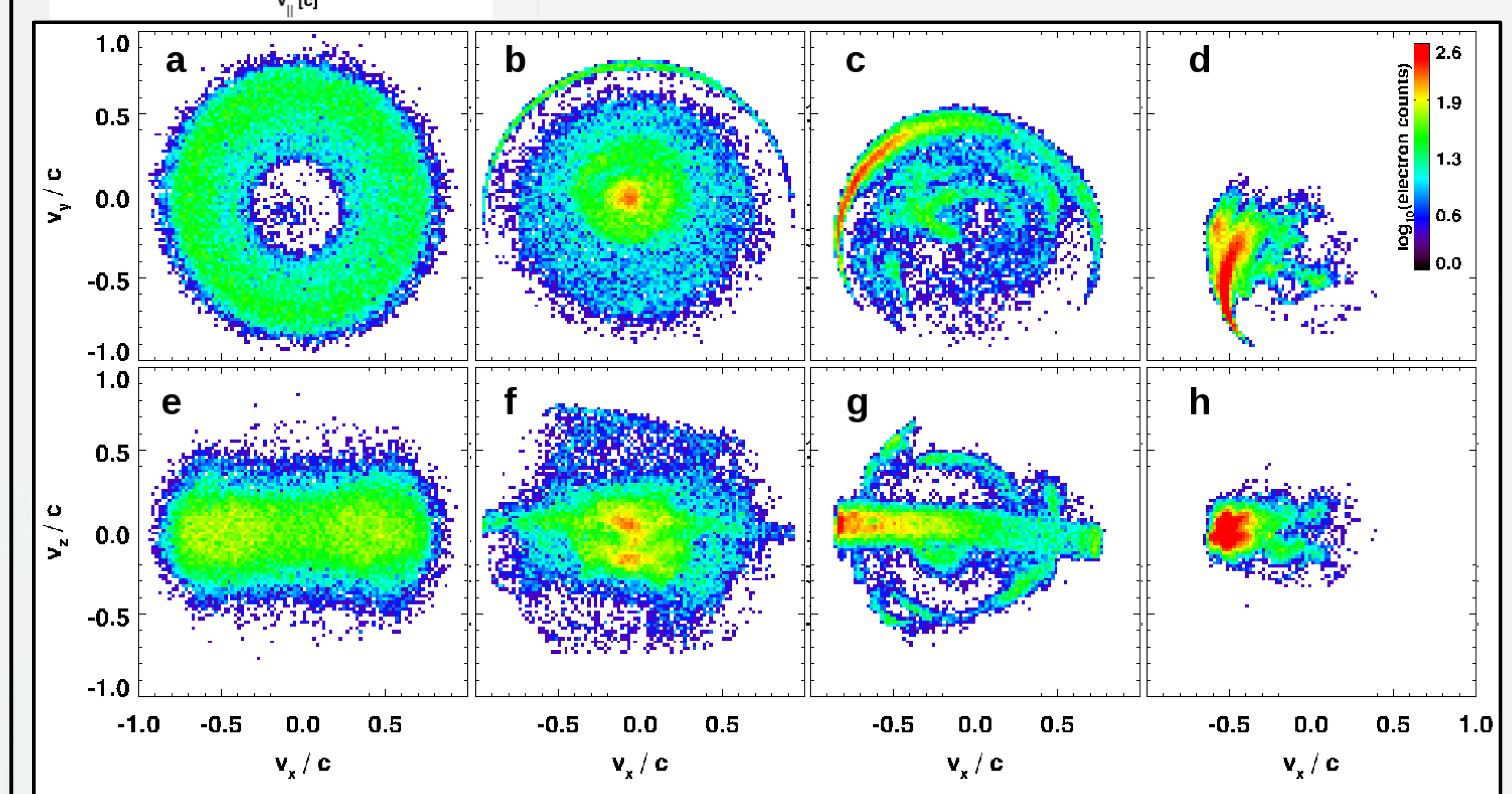
Anisotropy Associated with the Electron Outflow Jet

Instability Analysis: isotropizes quickly.



Spatial evolution: New highly anisotropic structures: **ring** distribution (a,e & white bins) and **arc** distribution (b,f & c,g). (Green bins correspond to distributions in a-h below.)





Conclusions and Implications

♦ After the peak in the reconnection rate occurs, electron anisotropy develops and persists in reconnection exhaust regions.

♦ New unstable ring and arc distributions found in open exhaust region between electron diffusion region and primary magnetic island.

♦ Consistent anisotropies as predicted by the simulation are found in Cluster data.

♦ These simulation predictions may be used in conjunction with future data from NASA's Magnetospheric Multiscale (MMS) mission to delineate the magnetic sub-domains in the ion diffusion region.

ACKNOWLEDGEMENTS:

Research at UNH is supported in part by NSF grants PHY-0903923 and AGS-1202537. This work is also supported by a UNH CEPS Graduate Fellowship. We wish to thank the PEACE team and the ESA Cluster Active Archive for providing data.

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